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INVESTIGATION OF THE EFFECTS OF EXTERNAL CURRENT SYSTEMS ON THE MAGSAT DATA UTILIZING GRID CELL MODELING TECHNIQUES

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16. Abstract

The overall objective of this effort in support of the Magsat project is to study the feasibility of modeling magnetic fields due to certain electrical currents flowing in the earth's ionosphere and magnetosphere. This sixth quarterly status and technical progress report discusses progress made in reducing the Magsat data and displaying magnetic field perturbations caused primarily by external currents. We describe a periodic and repeatable perturbation pattern that arises from external current effects but which will appear as unique signatures associated with upper middle latitudes on the earth's surface. The report also discusses initial testing of the modeling procedure that has been developed to compute the magnetic fields at satellite orbit due to current distributions in the ionosphere and magnetosphere. The modeling technique utilizes a linear current element representation of the large-scale space-current system.

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I. INTRODUCTION

The overall goal of this investigation is to study the feasibility of modeling the magnetic fields produced by certain electrical currents flowing in the earth's ionosphere-magnetosphere system. Vector magnetic field measurements from the near-polar orbiting Magsat satellite contain, in addition to the main geomagnetic field and crustal anomaly fields, contributions that arise from these external currents. In fulfilling the ultimate goals of the Magsat project, it is desirable that the external current effects be identified in the observations and subsequently separated from the internal field. The objective of this investigative effort will be to determine the capability of a modeling procedure to facilitate the separation of these external and internal components.

The approach of this feasibility study shall be to develop forward modeling procedures through which the magnetic effects of model currents may be derived. It is intended to include, separately, the equatorial electrojet, S_q currents, and the effects due to auroral zone and polar cap currents including the high latitude ionosphere-magnetosphere coupling currents. In each case candidate current systems will be devised and resulting 'typical' magnetic field signatures calculated for comparison with Magsat observations.

II. ACCOMPLISHMENTS DURING REPORTING PERIOD

1. Data Reduction

Previous quarterly reports have traced the development of software programs to read the Magsat Chronicle format data tapes on a U.T.D. PDP 11/45 computer, to printout either the orbital data alone or both orbital and magnetic field-values from both scalar and vector magnetometers for a specified time period contained on the source tape, and to plot using a high resolution interactive vector graphics terminal each of three resultant magnetic components and the scalar field deviations with respect to a spherical harmonic model field.

The desire to visualize, with respect to the auroral oval, the Magsat derived magnetic perturbations along the orbit path has prompted us to develop as a first step, an orbit plotting program. Ultimately this program will be able to display horizontal magnetic perturbation vectors at regular intervals along the satellite orbit. The entire sequence of Magsat orbits in magnetic local time, invariant latitude coordinates over northern latitudes (> 50°) is shown in Figure 1 for November 4, 1979. Note that as universal time advances through the day beginning in the upper left plot the orbital path of the satellite progresses across the polar ionosphere from the dayside of the polar cap to the nightside. Those orbits occurring during the first few hours of the day pass through or close to the so-called magnetospheric cusp where there are unique currents. At later universal times (near 1300 UT) the satellite cuts lie along or near the 0600-1800 magnetic meridian where the high latitude current pattern differs from that near the cusp. Later the orbit plane passes on the nightside of the 0600-1800 meridian and then returns to the dayside before midnight. Thus due to the location of the Magsat orbit and to the offset of the Magnetic pole relative to the geographic pole there is a systematic and repeatable 24-hour periodicity in the location of the satellite orbit with respect to the auroral and polar currents.

It follows that there will also be a systematic and repeatable 24 hour pattern in the magnetic perturbation signatures derived from the Magsat data. To demonstrate this repeatability we have selected a sequence of six orbits over the northern high latitudes on each of three different days. Figure 2 illustrates the remarkable similarity between the Magsat orbital paths for similar universal times on each of the three days. The sunward components of the relative magnetic perturbations for each of the 18 passes (two missing) are shown in Figure 3 with the same relative positions as in the previous figure. The day to day similarity of the perturbations on each of the three days during identical universal time periods is apparent as is the consistent change in the character of the perturbation

signature with increasing universal time during each day. During the early hours of the day (02-08 UT) the sunward component perturbations appear to be highly structured with a tendency for a positive perturbation over the center of the polar cap. At later times as the satellite orbit approaches the dawn-dusk magnetic meridian a nearly constant positive top hat develops with steep negative perturbations on either side of the polar cap. The dawn-dusk component of the magnetic field is shown for the same orbits in Figure 4. Again there is a systematic variation with universal time. Near the 0600-1800 meridian the perturbation signature is negative on the afternoon side of the polar cap and positive on the morning side. At later times both sides of the polar oval display negative D-component perturbations.

In addition to addressing the repeatability and overall constancy of the polar external current systems, the significance of these periodic and repeatable patterns lies in their potential effect on crustal anomaly studies. An example will illustrate the problem. Consider a particular region of the earth's surface centered at some intermediate geographic latitude, say at 60°N. The magnetic field attributed to crustal anomalies within this region is determined from magnetic perturbations deduced from Magsat observations taken when the satellite passes over the surface location in question. All Magsat passes over the location in question will occur at one or the other of two particular universal times, namely when the earth rotates through the orbital plane of the satellite. Thus each point on the ground has magnetic values associated with it that are taken at only two specific and unique universal times. Since at each particular universal time there is a consistent and unique magnetic perturbation associated with the external currents, the magnetic signature attributed to each surface location will have a consistent component due to the external high latitude currents as well as to any crustal anomaly that might be present. Thus great caution must be exercised when inferring magnetic anomalies at middle and high latitudes. Simply removing temporal variations or picking magnetically quiet days will not remove the consistent and repeatable external current

effects discussed here.

2. Field Modeling

Previous quarterly status reports have chronicled the development of a modeling technique to describe the magnetic perturbations produced at satellite orbit by an assumed ionospheric and Birkeland current system. This modeling routine is currently undergoing verification testing of its component subroutines.

Our modeling capability now allows us to make direct comparisons between model predictions and actual Magsat perturbations by additional software that allows us to calculate along an actual Magsat orbit the magnetic perturbations that would be seen at the satellite for an assumed current distribution. This gives us the capability for direct comparison between measured and predicted perturbation fields. By successive iteration of the input current system the current distribution that yields the best fit between the measured and predicted magnetic perturbations can be determined.

3. Other Activities

During this quarter a paper describing initial findings of our polar current system modeling was accepted for publication to the Geophysical Research Letters. The major results of this paper, entitled "A Technique for Modeling the Magnetic Perturbations produced by Field-Aligned Current Systems" were summarized in previous quarterly reports.

III. PROBLEMS ENCOUNTERED AND RECOMMENDATIONS

The anomaly reported last quarter, which appeared during attempts to read a number of Magsat data tapes, appears to be limited to some fraction of the 1600 bpi chronfin tapes received at UTD. We are currently in the process of determining the number of tapes involved so that replacements can be requested.

At the present time we do not anticipate that this problem will have a substantial effect upon the investigation.

IV. PLANS FOR NEXT REPORTING INTERVAL

The primary goal of this investigative effort is to develop field modeling

techniques for the near-earth magnetic field arising from external currents. Such development cannot successfully be carried out without concomitant study and analysis of the actual Magsat data. Hence again during the forthcoming quarter continuing emphasis will be placed on the use of Magsat data to guide our selection of input current systems for direct comparison between predicted magnetic perturbations and those derived from the Magsat data. To this end we intend to determine the magnetic perturbations for a large number of Magsat passes over polar latitudes ($\Lambda > 50°$) for both northern and southern hemispheres.

The linear element field modeling procedure will continue to undergo testing during the next reporting period. The emphasis will be placed upon utilizing the flexibility built into the software to choose diverse sets of initial current configurations. One such current configuration will be provided by the Alaska group, which, under the direction of S.-I. Akasofu, has been using the Kisabeth technique to model the current distributions that produce magnetic perturbations in the observations from a meridian chain of magnetometers located in Alaska. Using our modeling procedure we will compute the Birkeland currents required for current continuity and then compute the resulting magnetic perturbations expected both on the ground and at satellite altitude. Direct comparison between our predicted ground level perturbations and their initial input data will permit an assessment of the validity of the modeling technique.

It is also planned that the modeling technique should ultimately include effects due to currents in the S_q current system and in the equatorial electrojet. These currents have not until now been included in the model. During the forthcoming quarter we will begin to develop additional models of the magnetic field contributions from these currents that can be added to the polar current effects presently being analyzed.

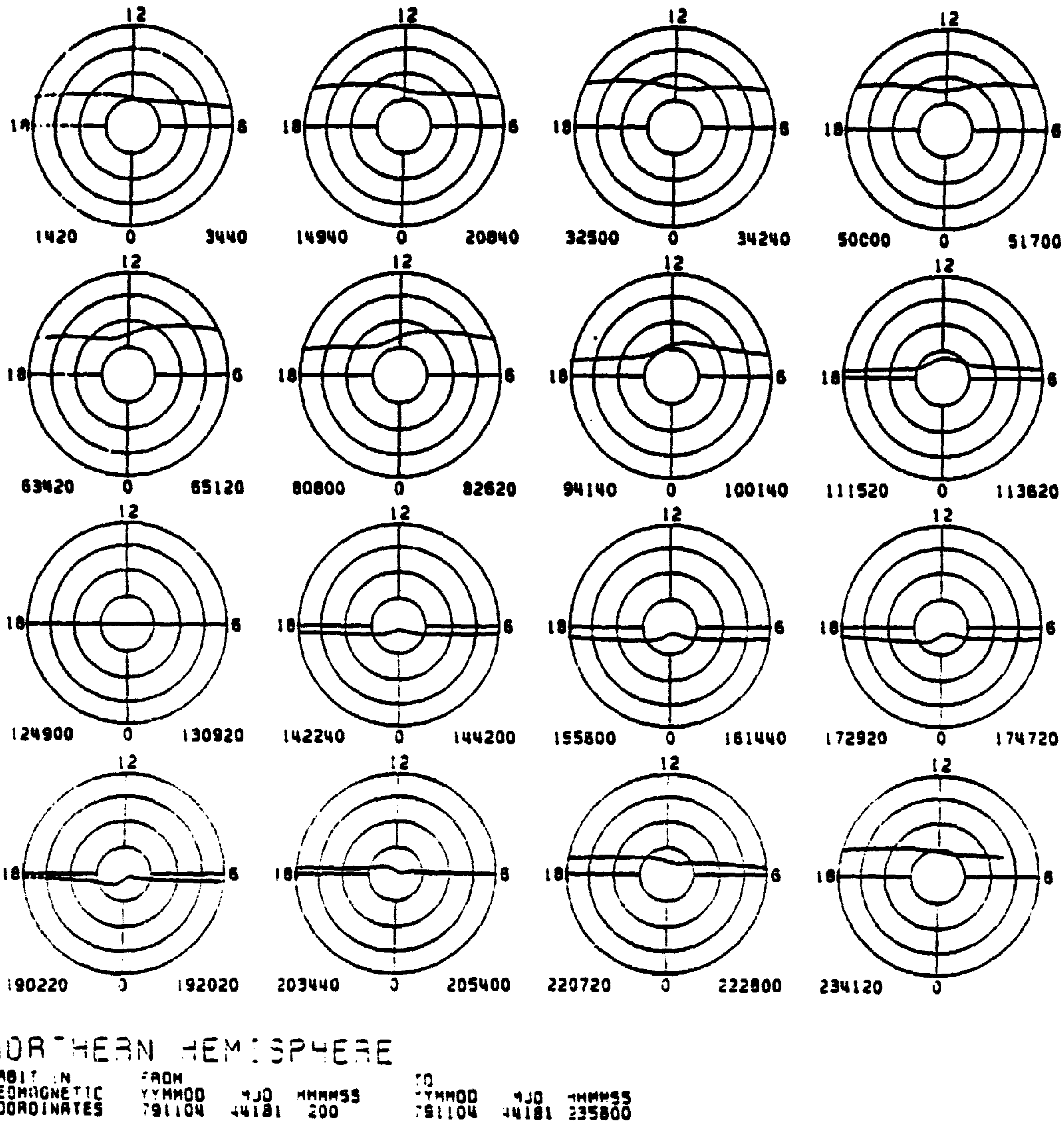
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Figure 1

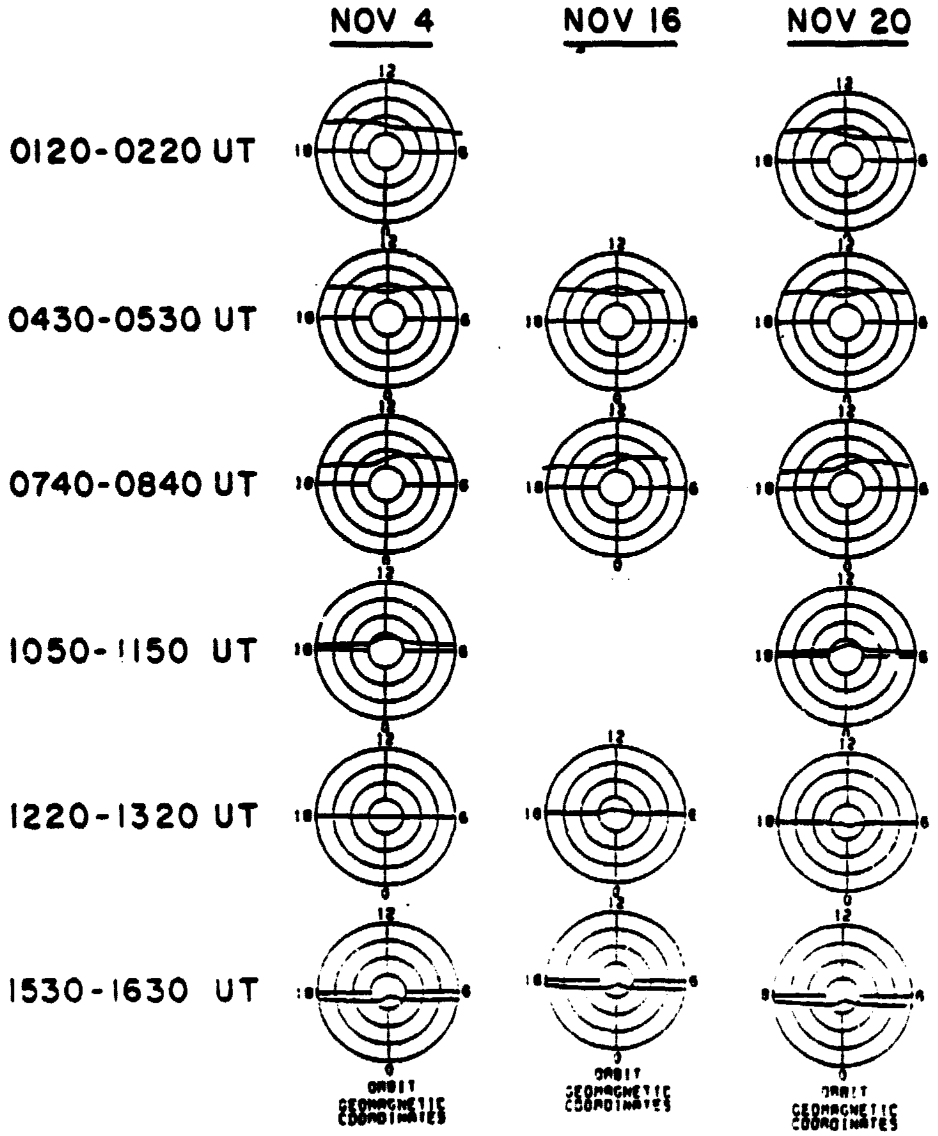
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Figure 2

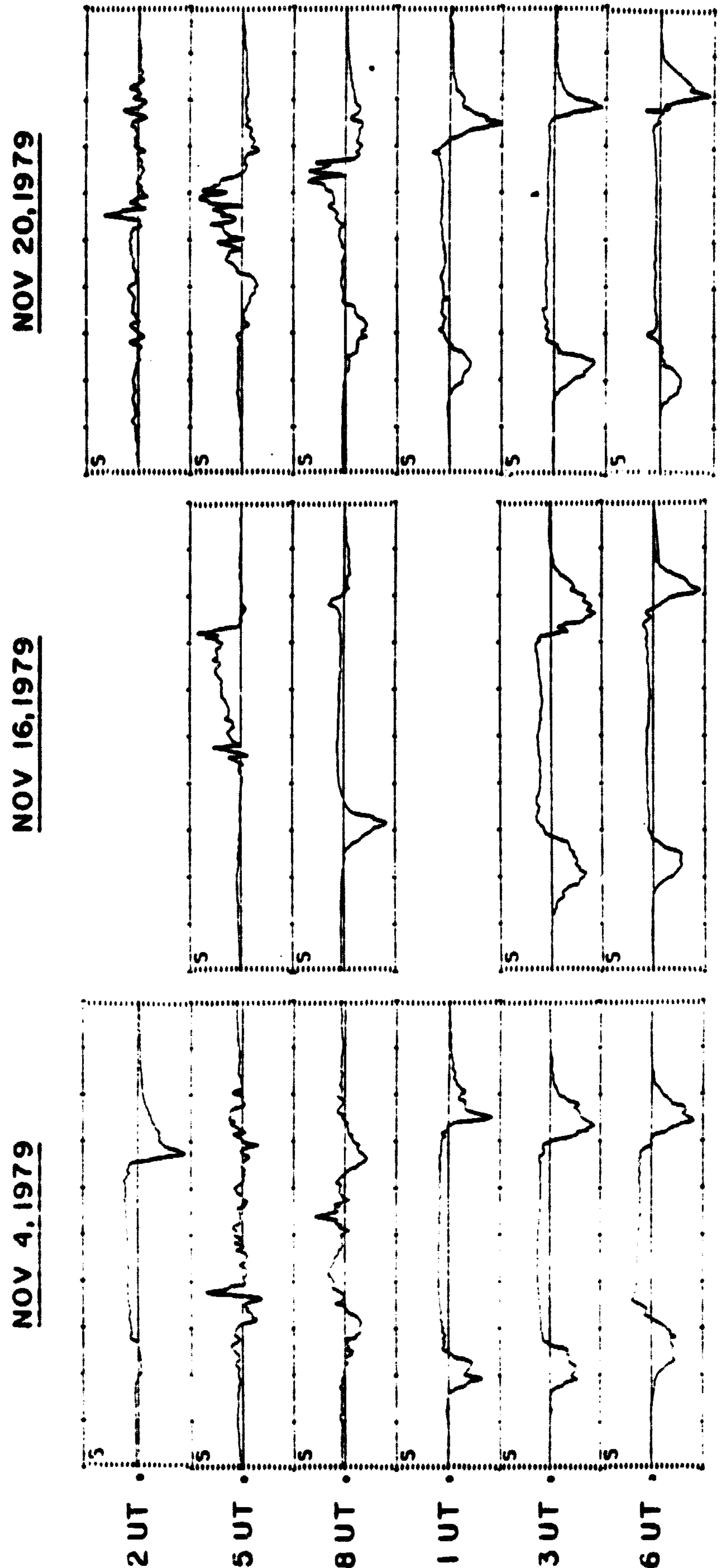
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Figure 3

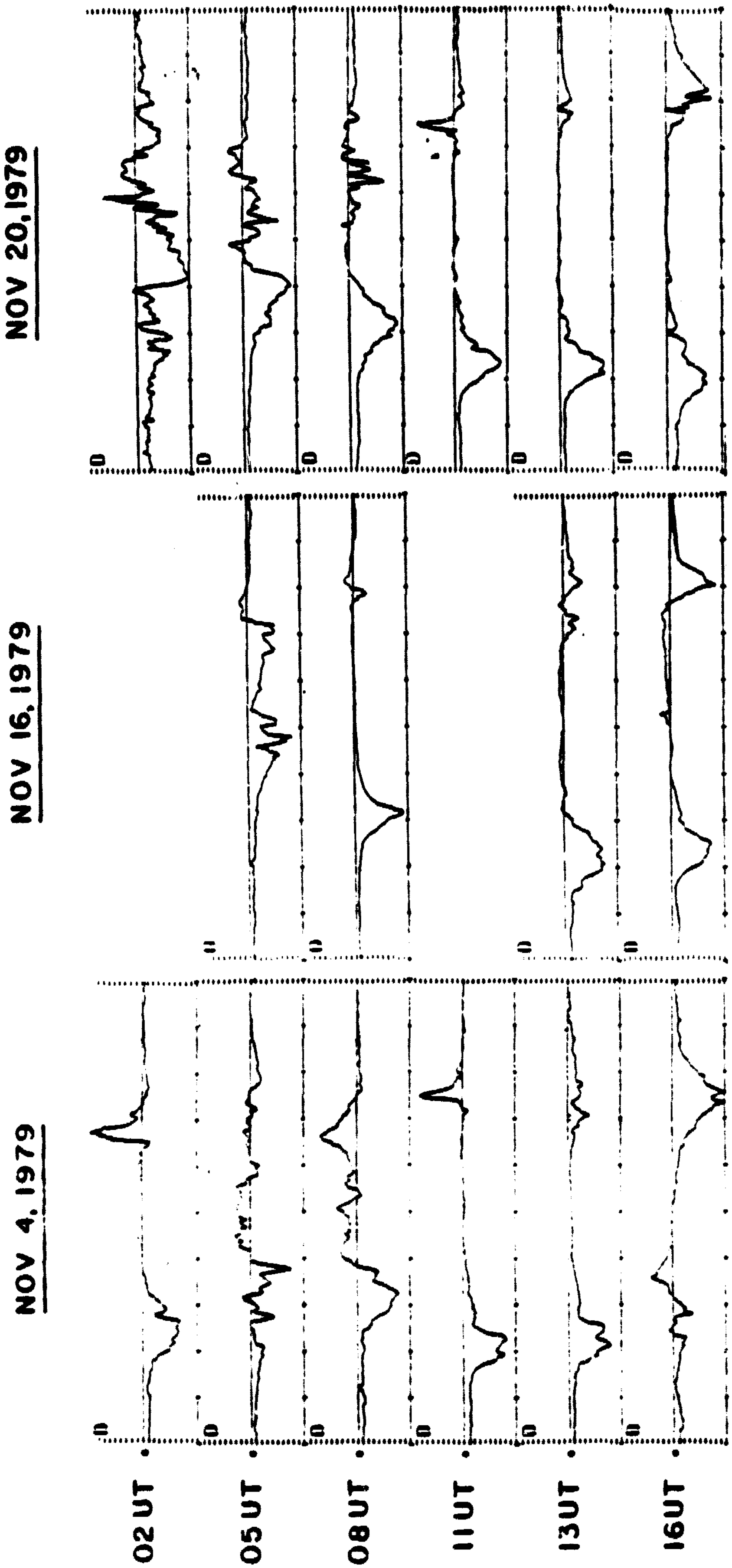

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Figure 4